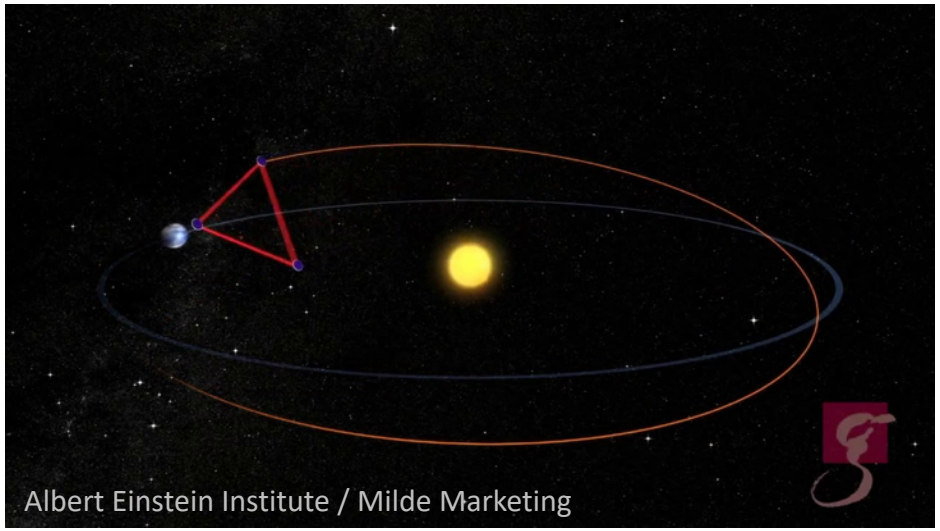
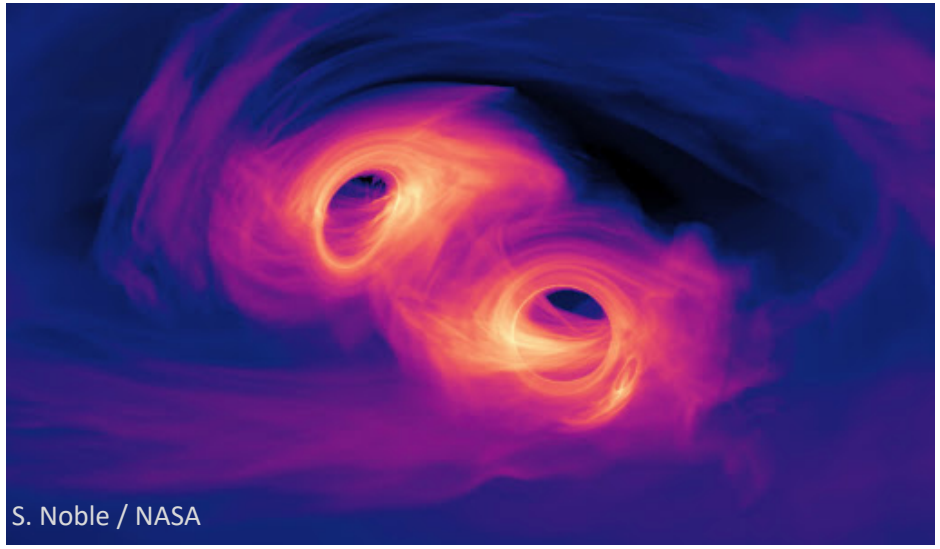
Update on LISA and NASA's Activities

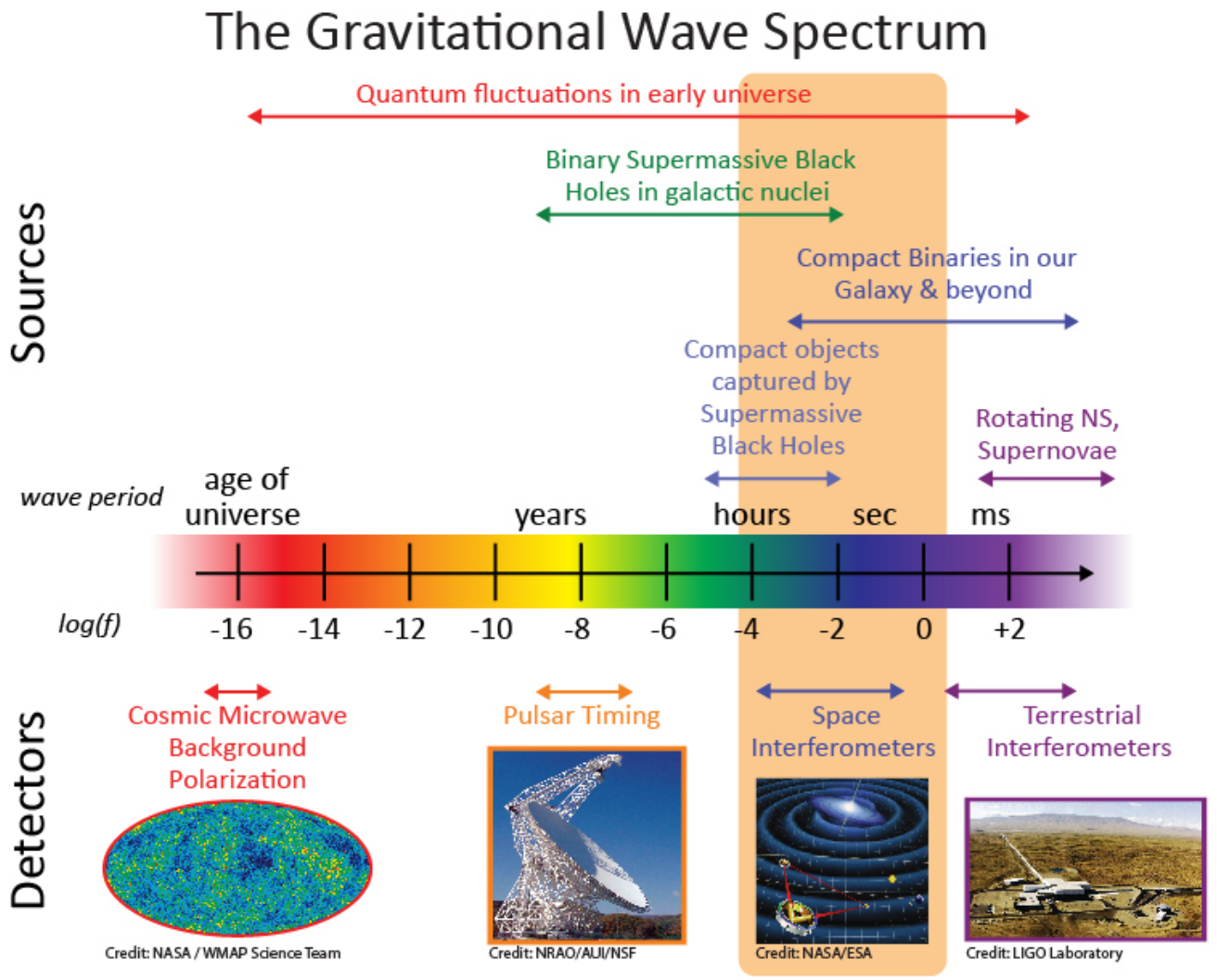
Ira Thorpe, NASA/GSFC
NASA LISA Study Scientist
GW Science Interest Group
237th Meeting of the American Astronomical Society
January 11th, 2021





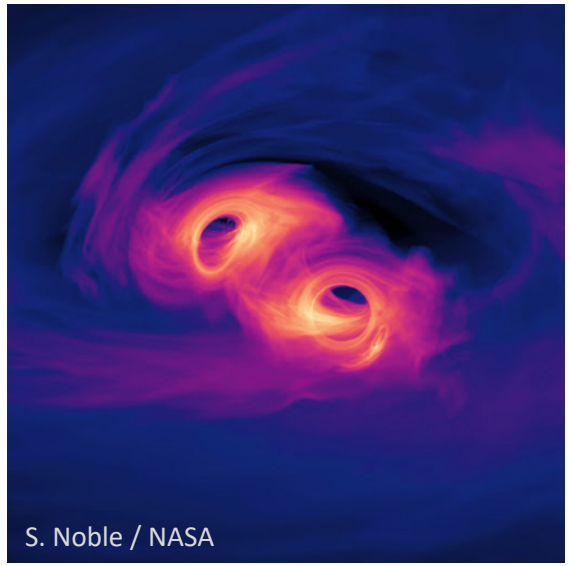
LISA Science Goals

- First GW observatory in the milliHertz band
- Tens of thousands of sources of many varieties
- Wide applications in astrophysics, cosmology, fundamental physics, etc.



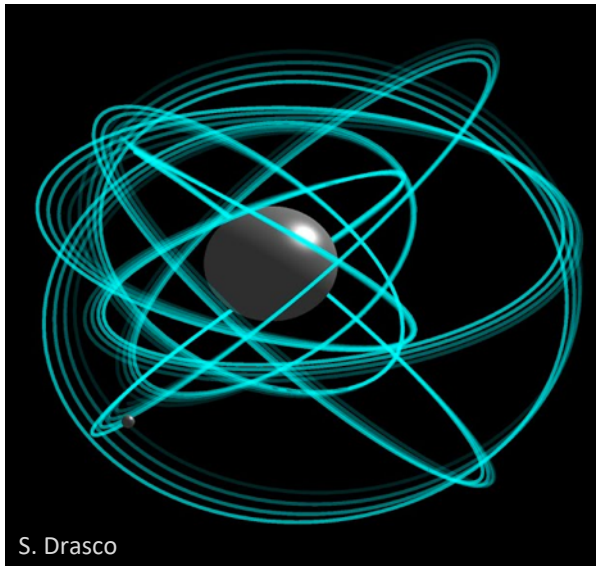
Science Highlights

Mergers of Massive BHs



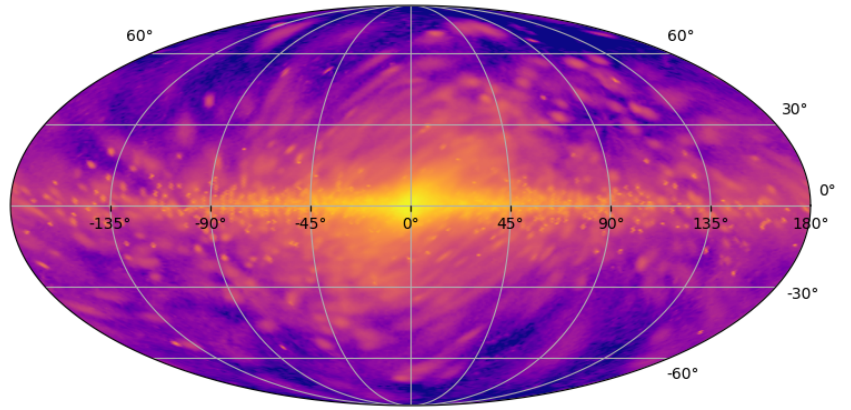
- $10^3 M_\odot$ ~ $10^8 M_\odot$
- $1 \lesssim z \lesssim 20+$
- D, M, m, χ, etc. at % level
- MBH formation and co-evolution with galaxies
- Potential EM counterparts?

Extreme Mass-ratio Inspirals



- BH analog of a TDE
- Extreme probe of strong gravity
- Probe high-mass demographics and dynamics of nuclear clusters

Ultra-compact binaries



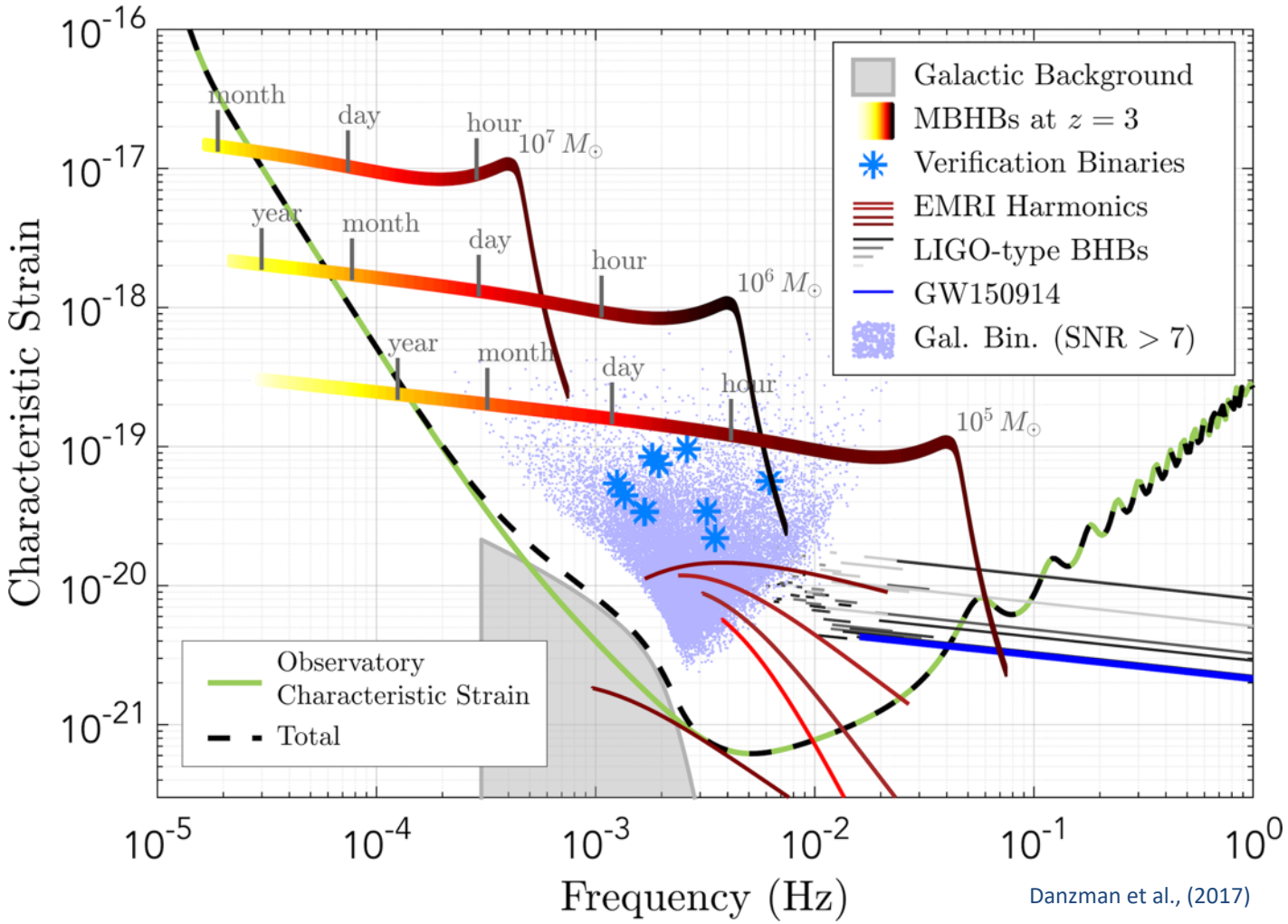
Lackeos, Littenberg, Thorpe

- ~10^4 resolved binaries (WD-WD, WD-NS, etc.)
- Unresolved galactic foreground
- Guaranteed multi-messenger sources
- End states of stellar + binary evolution, tracer of Milky Way formation history, binary astrophysics, etc.

+ Exotica (cosmic string cusps, cosmological GW background, exoplanets!)

Unique Data Set

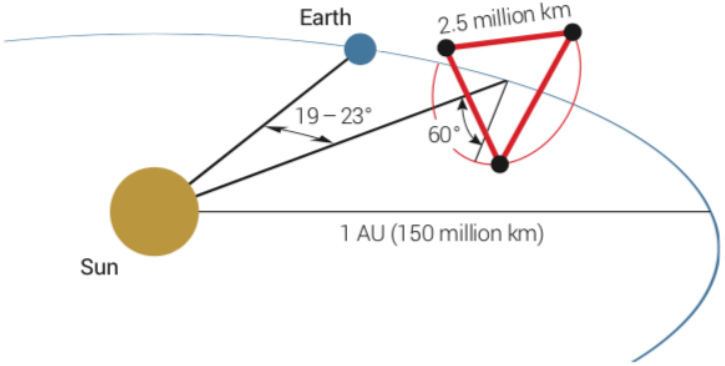
- All-sky monitor
- No “pointing”
- Both transient and persistent sources
- Gradual buildup of information
- Global fit required to extract individual signals

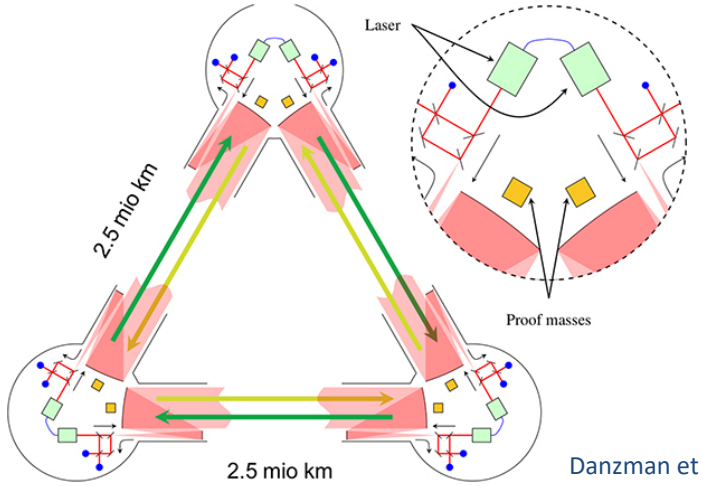


Danzman et al., (2017)

Mission Concept Overview

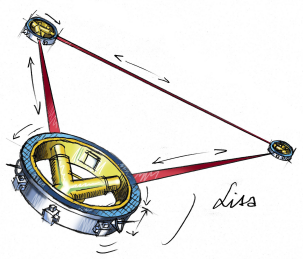
- **3-arm triangular constellation**
  - 2.5Mkm nominal arm lengths
  - Earth-like heliocentric orbit, ~50Mkm behind
- **Freely-falling test masses as inertial references**
  - Electrostatic/interferometric sensing
  - Spacecraft micropropulsion
  - Non-contact charge control (UV photons)
- **Heterodyne optical interferometry**
  - 1.064um Nd:YAG laser light
  - ~1µcycle phase measurement
  - Stable optical systems (incl. 30cm telescopes)





Danzman et al., (2017)

Data Flow & Products



Raw telemetry

1dd28bb55d63f7fbc7b535abaf111a0f
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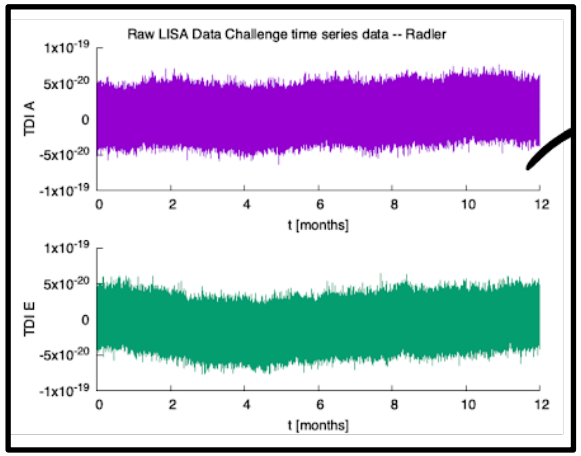
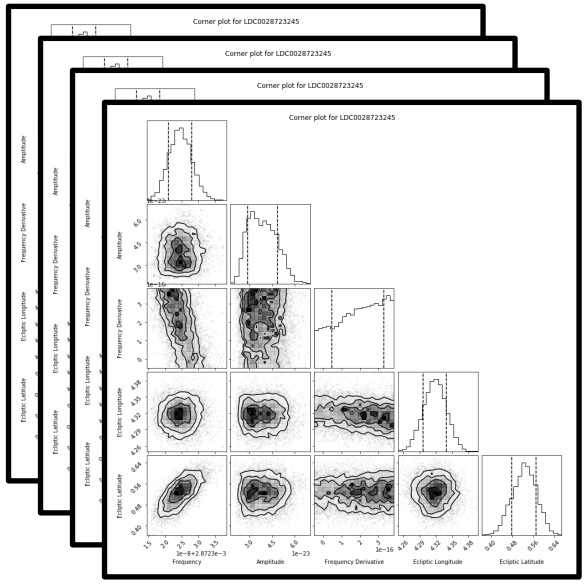
39d92449773301c823a66754687b0633
572863b73cb8accfcfd2673c91683437…

Constellation Synthesis

Constellation products (e.g TDI)



”Global Fit” pipelines



Search result(s)

Catalog Preparation

Consolidated catalogs & alerts

name	SNR	Frequency	Amplitude	Polarization	Ecliptic Longitude	Ecliptic Latitude
LDC0092117266	1300.580	0.009212	6.410701e-22	4.842525	4.940762	-3.058486
LDC0094454863	1014.450	0.009445	5.661734e-22	0.475508	5.219159	-2.948569
LDC0072193583	1001.230	0.007219	4.945779e-22	0.949107	3.816961	-3.752269
LDC0162054215	934.953	0.016205	6.472705e-22	6.253316	4.370268	-3.460044
LDC0021468055	878.972	0.002147	1.916480e-21	4.912222	5.011397	-3.726283

Organization

- Lead agency
- Spacecraft, LV, operations, payload elements
- Science Operations Center

lisa.esa.int

- Hardware contribution: payload-focused, ~$400M (Phase A-D LCC) including project management, systems eng., S&MA, etc.
- Science contribution TBD: participation in science ground segment, guest investigator program, archive functions, etc.

lisa.nasa.gov

- Major payload contributions
- Lead for science ground segment
- Lead for science applications

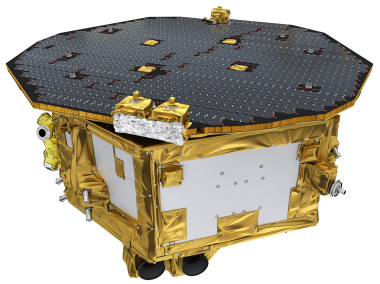
lisascience.org

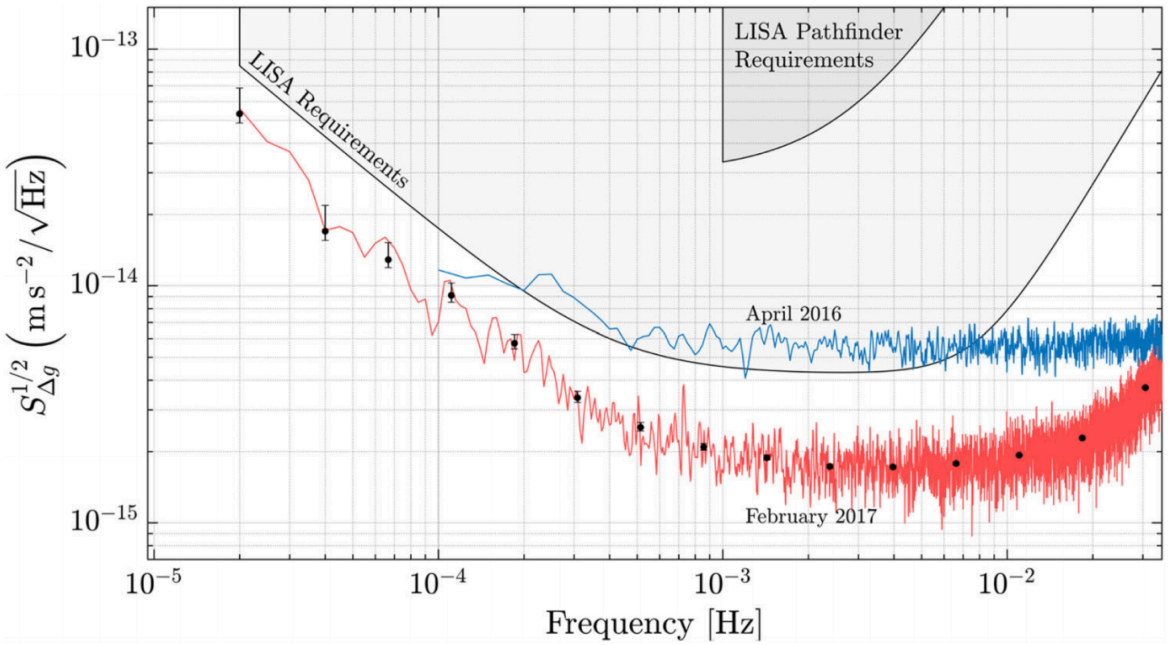
US & NASA Involvement

- **Following Community Recommendations**
  - Astro2000: Medium mission to follow GLAST (Fermi)
  - Astro2010: Large mission to follow WFIRST
  - 2016 Midterm: Significant participation in ESA-led LISA
  - Astro2020: Current participation presented as part of program of record
- **NASA LISA Study Office**
  - Pre-project office at GSFC implementing NASA's core LISA activities
  - Technical coordination with European partners
  - Development of enabling technologies
  - Laying foundation for participation in ground segment & science
- **NASA LISA Study Team**
  - Independent US-based researchers representing future US LISA user community to HQ
- **LISA Preparatory Science Program**
  - Targeted grant program to develop LISA science and future LISA researchers in the US

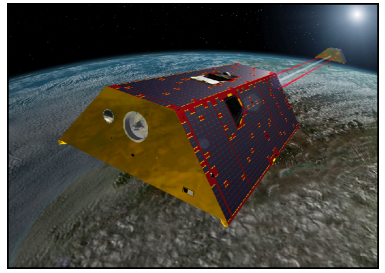
Flight Heritage for LISA

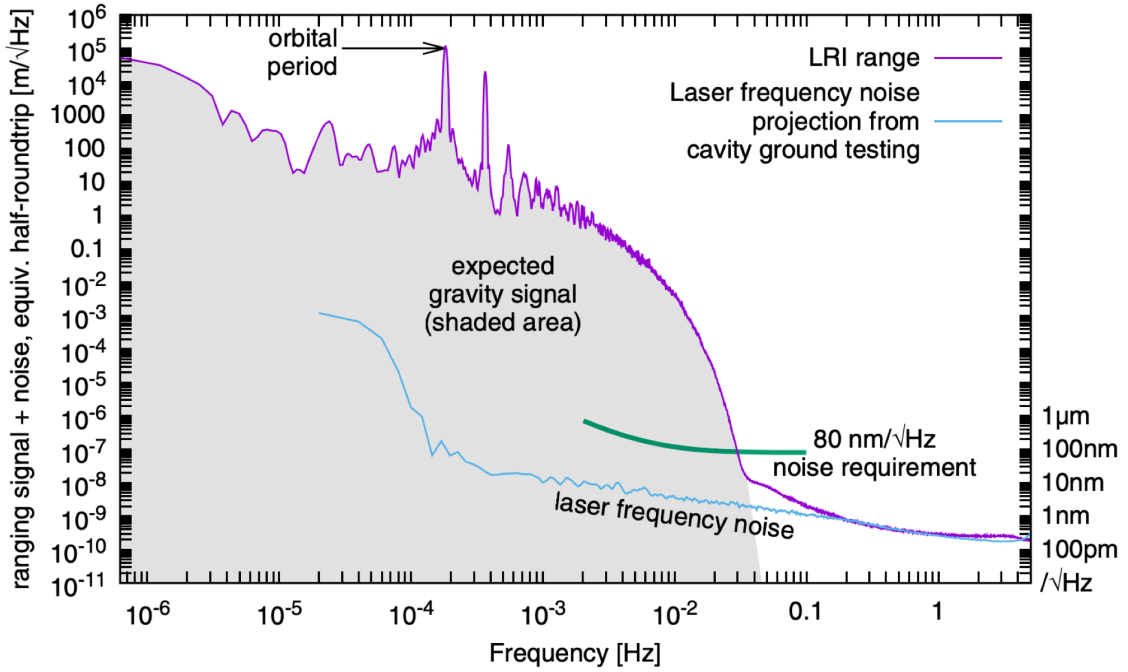
LISA Pathfinder





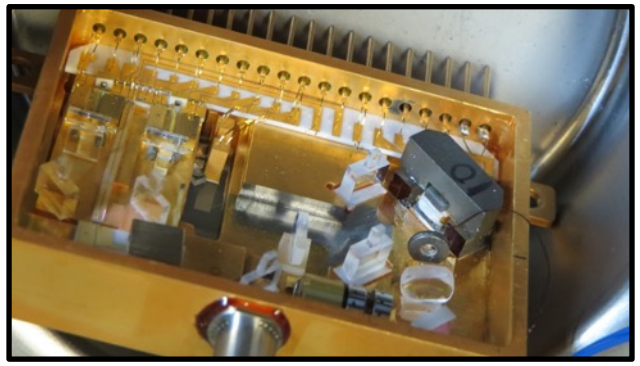
GRACE-FO LRI

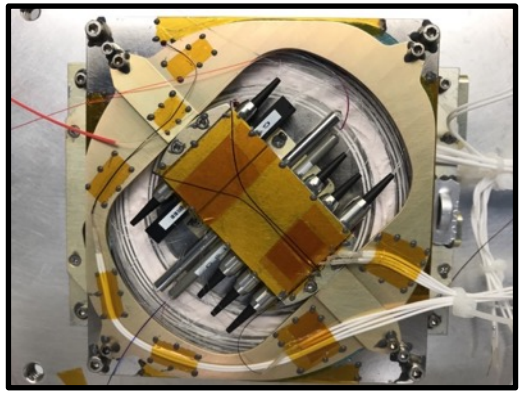




Technology Developments

- **Emphasis on technologies *not* included in LPF or GRACE-FO**
  - Telescopes (NASA)
  - High-power lasers (NASA)
- **Extend demonstration technologies from LPF/GRACE-FO to full-scale**
  - Charge Management (NASA/U. Florida)
  - Optical Benches (UK)
  - Phasemeters (Germany, NASA)
  - Test mass & housing (Italy++)

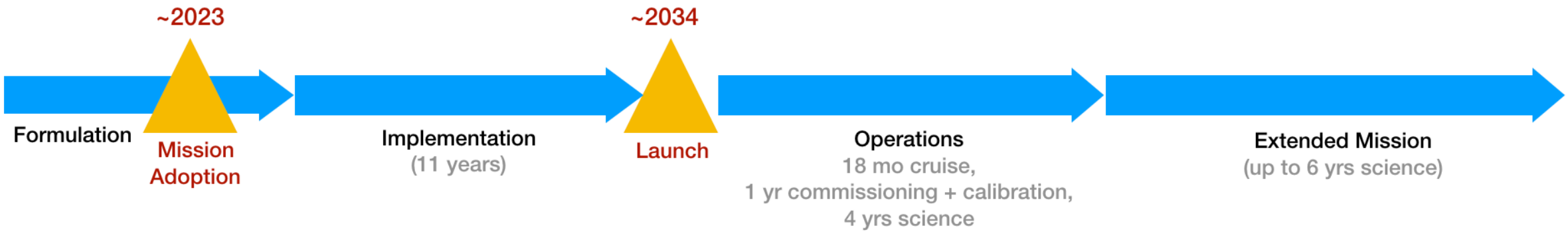




Clockwise from top left: uNPRO seed laser (GSFC/Avo Photonics), fiber laser power amplifier (GSFC/Fibertek), TRL4 Charge Management Device (UF/PSSL/NASA), LISA telescope rendering (GSFC).

Status and Outlook

- **Currently in “formulation” (ESA Phase A)**
  - Mission design
  - Requirements development
  - Demonstration of key technologies
  - Negotiation of roles and responsibilities
- **Recent progress**
  - Mission Consolidation Review, Nov. 2019
  - Mission Formulation Review, Fall 2021



Summary

- **Steady Progress being made on multiple fronts**
  - ESA, NASA, Consortium & industrial partners collaborating to consolidate mission design
  - Technology development proceeding on schedule
  - Initial work to understand complexity of science ground segment and associated data flow
  - Continued work on organizations and partnerships
- **Much work ahead of us**
  - Finalizing technology development
  - Consolidation of spacecraft and payload designs
  - Consolidation of roles and responsibilities
  - Transitioning to implementation phase

BACKUP

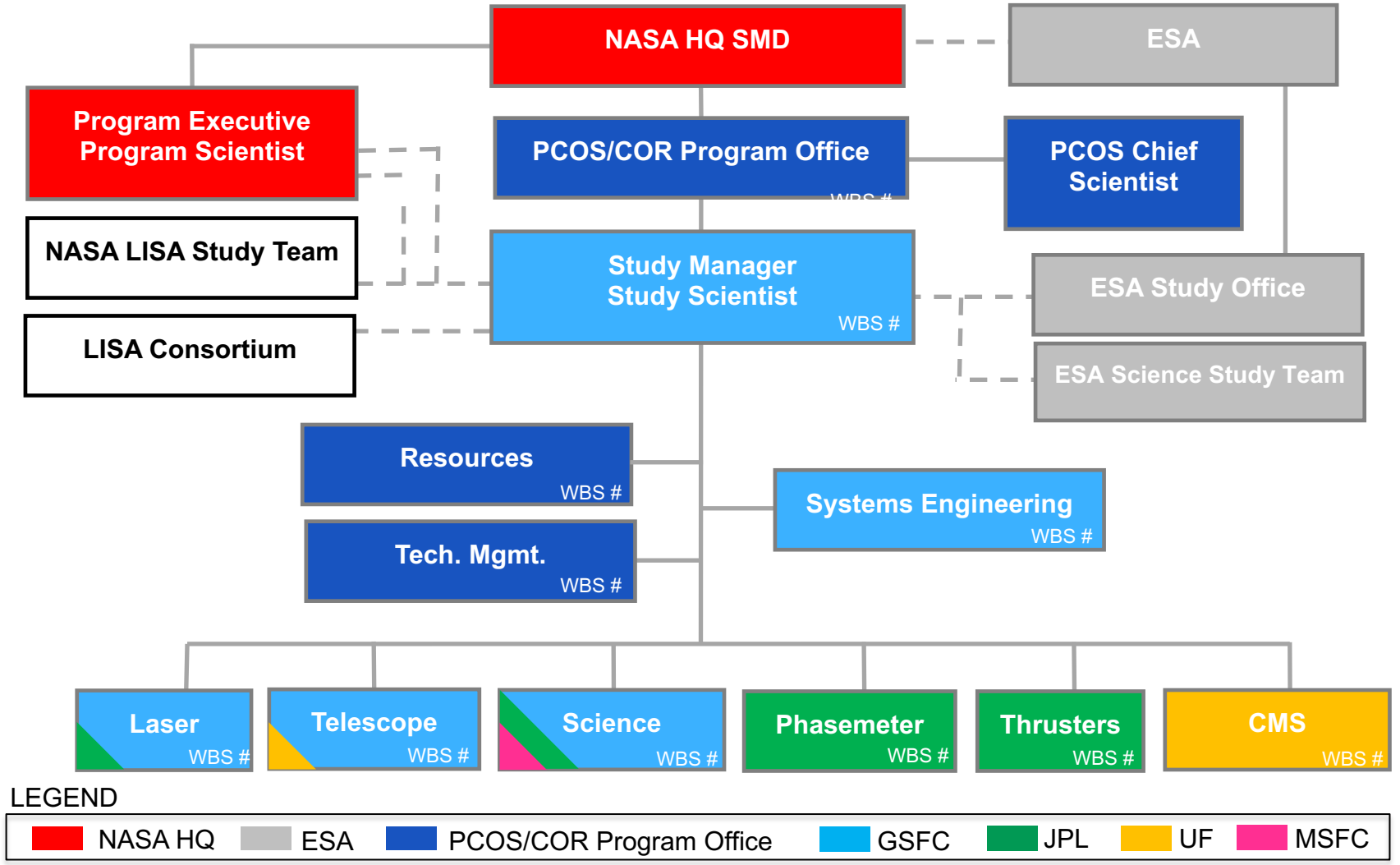
The LISA Consortium

- **Grassroots organization working to organize contributions to LISA external to ESA**
  - Payload contributions (systems engineering, subsystems, I&T, etc.)
  - Science ground segment contributions (analysis pipelines, data centers, etc.)
  - Science investigations
- **Governed by bylaws and implemented through management structure**
  - LISA Instrument Group (LIG)
  - LISA Data Processing Group (LDPG)
  - LISA Science Group (LSG)
  - …
- **Individuals and/or research groups apply and commit FTEs**
  - Expectation is that individuals will secure funding to support their commitments (e.g. from ESA Member States)
  - Option for “affiliate” members w/o commitment
  - US participants but no direct connection to NASA funding
- **Interfaces between LISA Consortium and ESA / NASA / US Community / etc. still TBD**
  - Technical authority
  - Intellectual property and publication policies
  - Data policies
  - …

NASA LISA Study Office

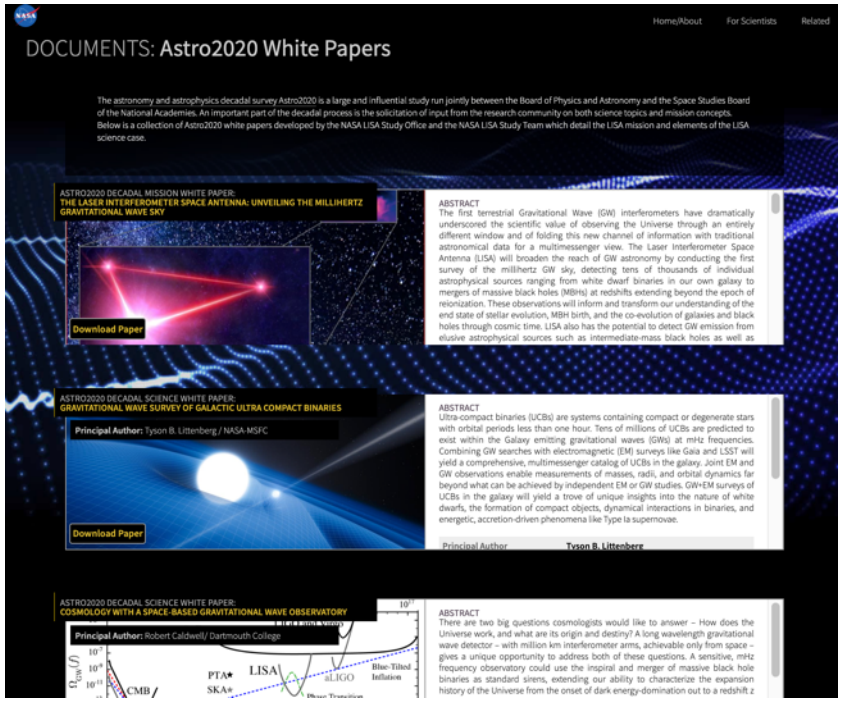
- **“proto-project”**
  - Conducts pre-formulation activities (NASA is pre-phase A)
  - Will evolve into formal NASA Project Office (~2021 TBD)
- **Hosted by Physics of the Cosmos Program at NASA/HQ**
  - Program responsible for managing science themes including gravitational waves
- **Executed by NASA field centers & partners**
  - GSFC: project management, science, and system engineering lead; telescope and laser development
  - JPL: science and systems engineering support; interferometry expertise and supporting technologies in micropropulsion and phase measurement
  - MSFC: science and science ground segment support
  - UF: charge management, telescope testing support

Organization Chart



Decadal Survey Activities

- **Science WPs**
  - Input organized by NLST
  - Participation from NASA Core Team, broader US community, European LISA community, etc.
  - 11 NLST-organized science WPs submitted
- **Mission WP submitted to APC call**
  - Summarized LISA science, mission concept, programmatics, and likely US role
- **RFI Responses**
  - Provided cost information in response to a request that came to NASA HQ
  - Responded to an RFI with specific questions from the from program panel on Particle Astrophysics and Gravitation on Jan 14th
- **Other information**
  - Supporting documentation (FAQs, detailed docs, etc.) on lisa.nasa.gov



Astro2020 whitepapers available at:
https://lisa.nasa.gov/documentsAstro2020.html

LISA “Mission” Whitepaper

- **Relevance**
  - Astro2020 guidance was that WFIRST/Athena/LISA WPs were “not necessary”
  - LISA community felt strongly that an APC WP gave an opportunity to clarify LISA’s context in the science program and NASA’s potential roles
- **Highlights**
  - Science case summary
  - Mission description
  - Summary of technical readiness incl. LPF and LRI heritage
  - Outlook for schedule and partnerships
- **Outlines potential “upscopes”**
  - Intended to support the Astro2020 charge to evaluate upscopes, descopes, and cancellation.
  - Broad-brush scenarios for additional contributions beyond nominal hardware contributions

https://lisa.nasa.gov/downloads/forScientists/whitePapers/LISA_Astro2020_APC_final.pdf